

Progress Report

DOE-NEER Grant Program

DE-FG07-00ID 13921

"Development and Applications of Time of Flight Neutron Depth Profiling"

Cornell University (DOE-Prime)

College of Engineering/The Pennsylvania State University

Report Period: **May 5, 2003 to May 04, 2004**

During the period of May 5, 2003 to May 4, 2004 the testing of conventional NDP was completed at the Radiation Science and Engineering Center beam facility at PSU. A layout of the beam facility is shown in Figure1 below. Several measurements were carried out using the Penn State NDP facility. The data obtained from PSU-NDP facility were compared with the measurements performed at UT-Austin NDP facility and Cornell University NDP facility using the same samples. The results of the measurements on implanted and borophosphosilicate glass wafers are given Figures 2-6, and shows good agreement with these measured data as well as computational results.

As the semiconductor device sizes get smaller, the need for proper analysis techniques becomes an important challenge. The devices will have dopants implanted at very low energies with total depth around 200 Å. Other analytical techniques such as SIMS are not capable of measuring such small thicknesses. Time-of-flight NDP, a new approach to NDP, seems to be promising to overcome the inherent resolution issue in the conventional NDP, and may become an analytical technique to fulfill this demand. The

premise is based on the fact that the time measurements can be made with far better resolution. The use of MCP detectors will eliminate the straggling issue in semiconductor detectors.

The depth resolution for TOF-NDP is expected to be 5-10 times better than that of the conventional NDP. A resolution of this magnitude will become an essential tool for semiconductor industry, where high-precision measurements are of paramount importance, in particular for quality assurance/control (QA/QC) purposes.

Time-of-flight NDP setup is near completion at PSU. All equipment including MCP's and electronics purchased, sample holder, detector holders and electron steering device designed and built. A schematic of PSU TOF NDP target chamber is shown in Figure 7. Trajectories of electrons and charged particles calculated, and tested experimentally with a Po-210 source. We expect to measure ^{10}B distribution in shallow junction devices with a few-nanometer resolution when the Penn State TOF-NDP system completed in fall 2004.

During the period of May 5, 2003 to May 04, 2004, an invited paper was prepared for the American Nuclear Society Annual meeting at Pittsburgh, PA (paper was presented on June 13-17, 2004 and published in Trans. American Nuclear Society, 90, 311 (2004)). Another invited paper was submitted to 11th International Conference on Modern Trends in Activation Analysis at University of Surrey, Gilford, England (paper was presented during the conference on June 20 –25, 2004 and will be published in the Journal of Radioanalytical and Nuclear Chemistry).

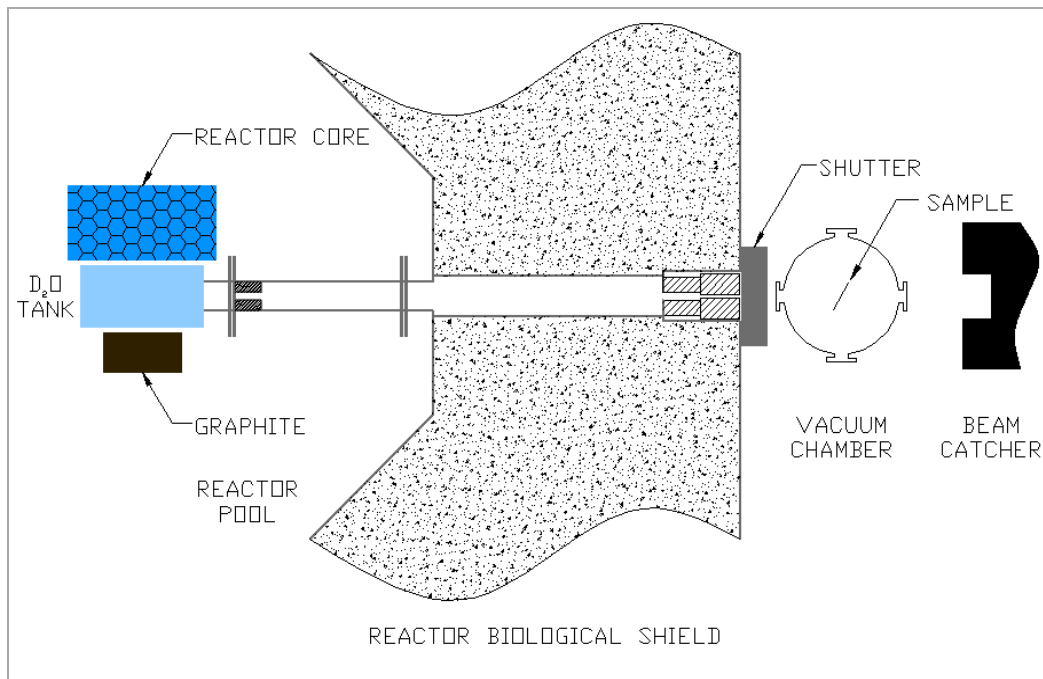


Figure 1. Schematic layout of Penn State University Breazeale Nuclear Reactor Beam Port #4.

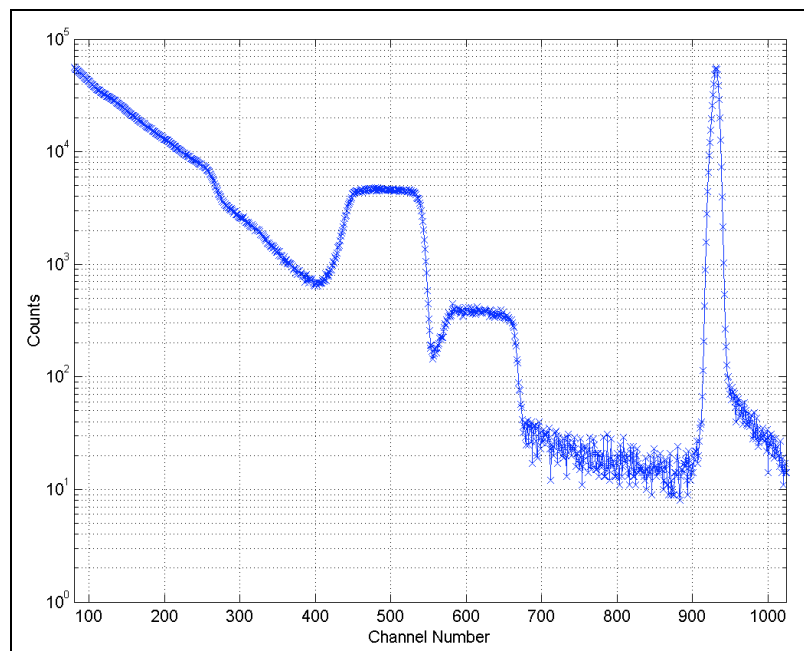


Figure 2. Penn State NDP measurement of the energy spectrum of particles emitted by the neutron-boron reaction.

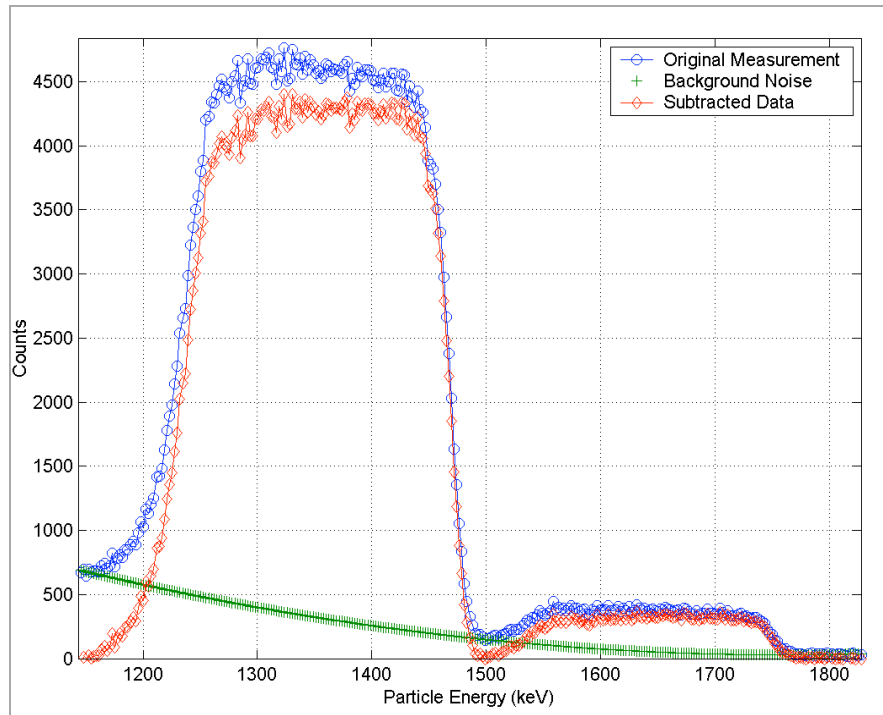


Figure 3. Alpha particle spectrum expanded from Figure 2.

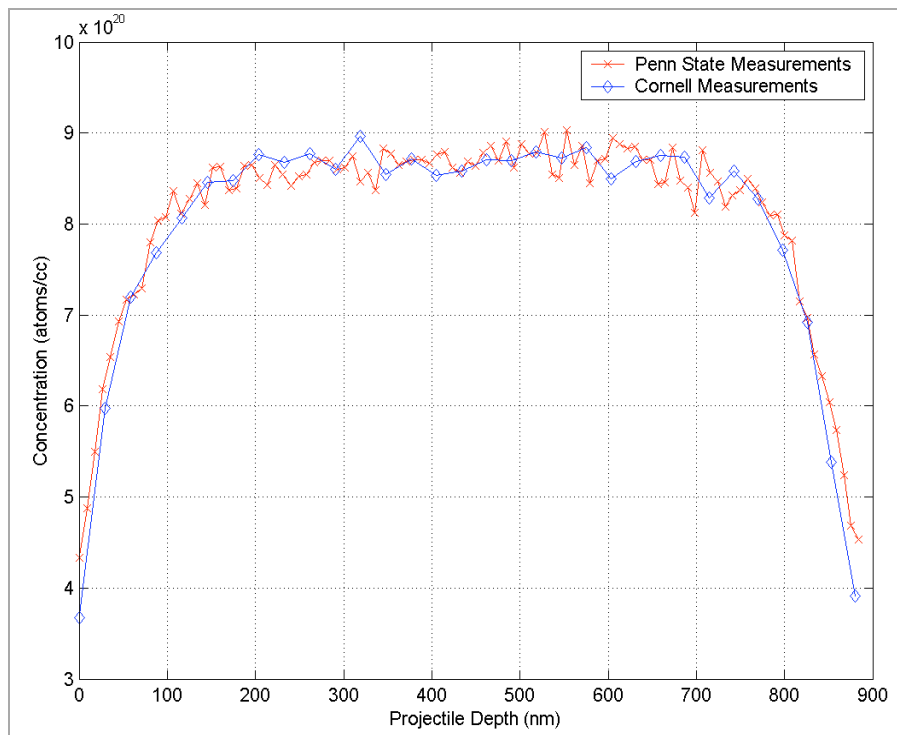


Figure 4. Boron density profile for a borophosphosilicate glass (BPSG) sample

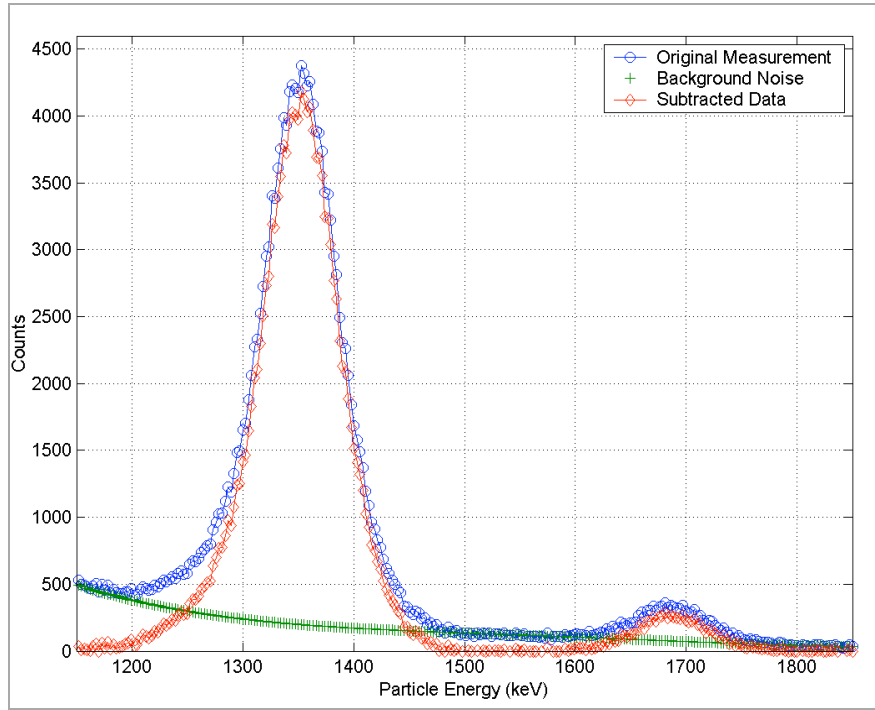


Figure 5. Alpha peaks from the neutron- ^{10}B reaction in a 120-keV ^{10}B -implanted silicon wafer

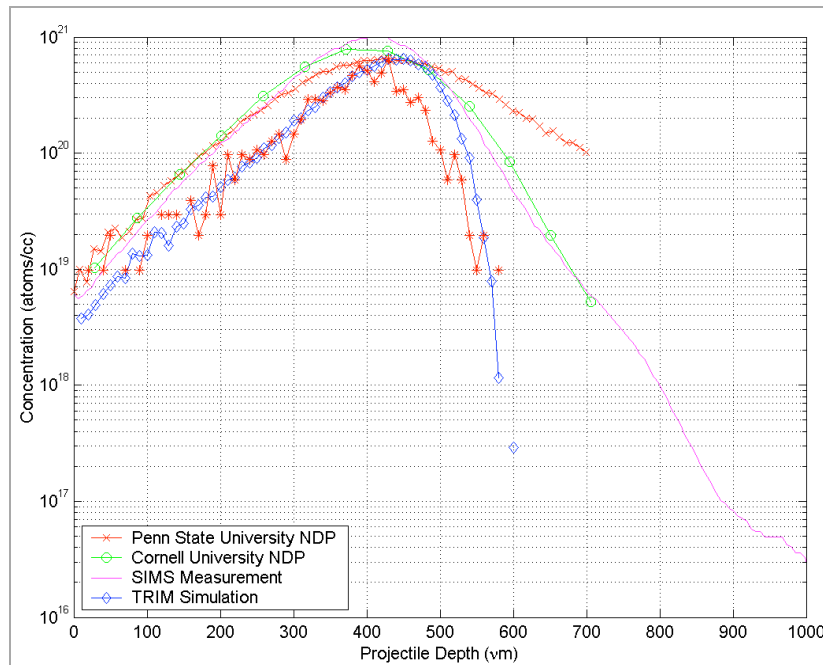


Figure 6. Comparison of different analytical techniques and simulations for 120-keV ^{10}B -implanted silicon wafer

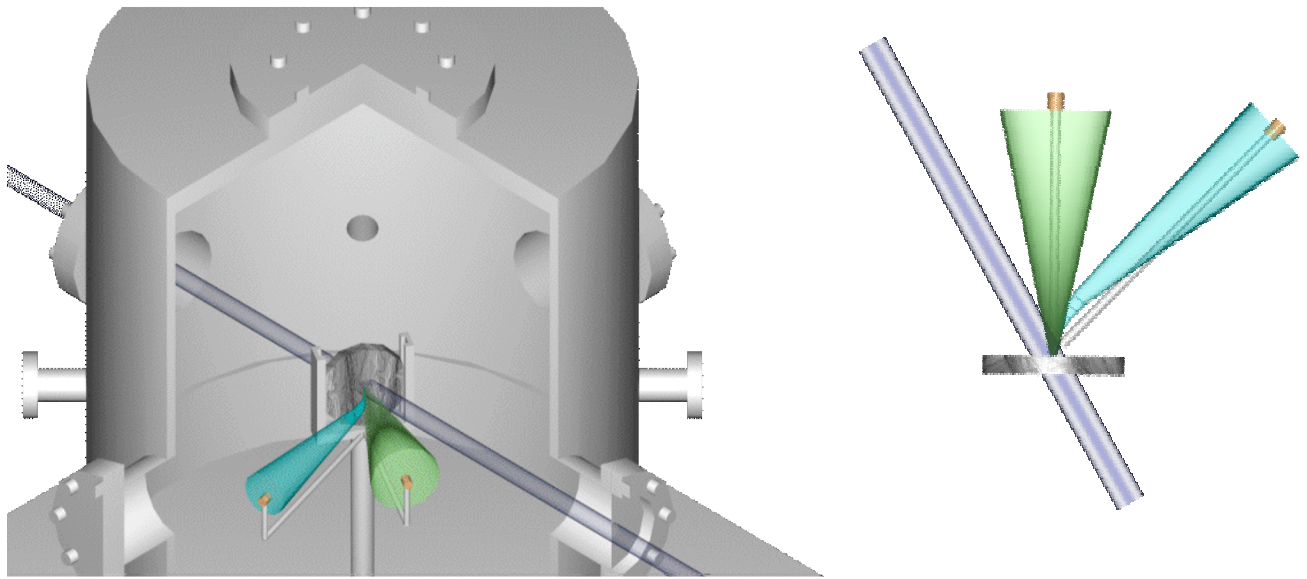


Figure 7. Cross sectional view of the time of flight experimental setup